Useful equations & constants

$$
\begin{aligned}
1 \text{ nm} &= 1 \times 10^{-9} \text{ m} \\
1 \text{ mm} &= 1 \times 10^{-3} \text{ m} \\
K &= 8.99 \times 10^{9} \text{ Nm}^2/\text{C}^2 \\
\epsilon_0 &= 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2 \\
\mu_0 &= 4\pi \times 10^{-7} \text{ T m/A} \\
c &= 3.00 \times 10^{8} \text{ m/s} \\
g &= 9.80 \text{ m/s}^2 \\
m_e &= 9.11 \times 10^{-31} \text{ kg} \\
m_p &= 1.67 \times 10^{-27} \text{ kg} \\
e &= 1.60 \times 10^{-19} \text{ C} \\
F &= \frac{K q_1 q_2}{r^2} \\
\vec{E} &\equiv \frac{\vec{F}_{on\ q}}{q} \\
\vec{E} &= \frac{Kq}{r^2}\hat{r} \\
p &= qs
\end{aligned}
$$

$$\vec{E}_{dip} \simeq \frac{2K\vec{p}}{r^3} \quad , \quad \vec{E}_{dip} \simeq -\frac{K\vec{p}}{r^3}$$

$$\lambda = \frac{Q}{L} \quad , \quad \eta = \frac{Q}{A}$$

$$E_{rod} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r\sqrt{r^2 + (L/2)^2}} \quad , \quad E_{line} = \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{r}$$

$$E_{ring,\,z} = \frac{KzQ}{(z^2 + R^2)^{3/2}} \quad , \quad E_{disk,\,z} = \frac{\eta}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right]$$

$$E_{plane} = \frac{\eta}{2\epsilon_0} \quad , \quad E_{cap} = \frac{\eta}{\epsilon_0}$$

$$E_{sur} = \frac{\eta}{\epsilon_0}$$

$$W = \vec{F} \cdot \vec{\Delta r} \quad , \quad W = \int_i^f \vec{F} \cdot d\vec{s}$$

$$W \equiv -\Delta U$$

$$U_{elec} = qEs$$

$$U_{elec} = \frac{Kq_1q_2}{r}$$

$$V \equiv \frac{U_{q+source}}{q}$$

$$V = Es$$

$$V = \frac{Kq}{r}$$

$$V_{ring,z} = \frac{KQ}{\sqrt{R^2+z^2}} \quad , \quad V_{disk,z} = \frac{2KQ}{R^2}\left[\sqrt{R^2+z^2} - z\right]$$

$$\Delta V = -\int_i^f \vec{E}\cdot d\vec{s}$$

$$\Delta V_{bat} = \frac{W_{chem}}{q} = \mathcal{E}$$

$$E_s = -\frac{dV}{ds}$$

$$\Delta V_{loop} = \sum_i (\Delta V)_i = 0$$

$$C \equiv \frac{Q}{\Delta V_C} = \frac{\epsilon_0 A}{d}$$

$$C_{eq} = C_1 + C_2 + \ldots$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$$

$$U_C = \frac{Q^2}{2C} = \frac{1}{2}C(\Delta V_C)^2$$

$$u_E = \frac{1}{2}\epsilon_0 E^2$$

$$N_e = i_e \Delta t$$

$$i_e = n_e A v_d$$

$$v_d = \frac{e\tau}{m}E$$

$$i_e = \frac{n_e e \tau A}{m}E$$

$$I = \frac{dQ}{dt} = e i_e$$

$$J = \frac{I}{A} = n_e e v_d$$

$$\sum I_{in} = \sum I_{out}$$

$$J = \sigma E$$

$$\sigma = \frac{n_e e^2 \tau}{m}$$

$$
\begin{aligned}
\rho &= \frac{1}{\sigma} \\
I &= \frac{\Delta V}{R} \\
R &= \frac{\rho L}{A} \\
P_{bat} &= I\mathcal{E} \\
P_R &= I\Delta V_R = I^2 R = \frac{(\Delta V_R)^2}{R} \\
R_{eq} &= R_1 + R_2 + \ldots \\
\frac{1}{R_{eq}} &= \frac{1}{R_1} + \frac{1}{R_2} + \ldots \\
\Delta V_{bat} &= \mathcal{E} - Ir \\
B_q &= \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2} \\
\vec{B}_q &= \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2} \\
\vec{B}_{I\,seg} &= \frac{\mu_0}{4\pi}\frac{I\Delta\vec{\ell}\times\hat{r}}{r^2} \\
B_{wire} &= \frac{\mu_0 I}{2\pi d} \\
B_{loop} &= \frac{\mu_0}{2}\frac{IR^2}{(z^2+R^2)^{3/2}} \\
B_{coil\ center} &= \frac{\mu_0}{2}\frac{NI}{R} \\
\vec{B}_{dip} &= \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{r^3} \\
\mu &= IA \\
\vec{F}_{on\ q} &= q\vec{v}\times\vec{B} \\
r_{cyc} &= \frac{mv}{qB} \\
f_{cyc} &= \frac{qB}{2\pi m} \\
\vec{F}_{wire} &= I\vec{\ell}\times\vec{B} \\
\vec{\tau} &= \vec{\mu}\times\vec{B} \\
\mathcal{E} &= v\ell B \\
I &= \frac{v\ell B}{R} \\
F_{pull} &= F_{mag} = \frac{v\ell^2 B^2}{R}
\end{aligned}
$$

$$
\begin{aligned}
P_{input} &= P_{dis} = \frac{v^2 \ell^2 B^2}{R} \\
\Phi_m &= \vec{B} \cdot \vec{A} = BA\cos\theta \\
\Phi_m &= \int \vec{B} \cdot d\vec{A} \\
\mathcal{E} &= \left|\frac{d\Phi_m}{dt}\right| \\
E &= cB \\
c &= \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3.0 \times 10^8 \text{ m/s} \\
\vec{S} &= \frac{1}{\mu_0} \vec{E} \times \vec{B} \\
I &= \frac{P}{A} = \frac{1}{2} c\epsilon_0 E_0^2 \\
p_{rad} &= \frac{F}{A} = \frac{I}{c} \\
I_{trans} &= I_0 \cos^2\theta \\
v &= \lambda f \\
n &\equiv \frac{c}{v} \\
\lambda_{mat} &= \frac{\lambda_{vac}}{n} \\
\theta_m &= \frac{m\lambda}{d} \\
y_m &= \frac{m\lambda L}{d} \\
\Delta y &= \frac{\lambda L}{d} \\
I_{double} &= 4I_1 \cos^2\left(\frac{\pi d}{\lambda L} y\right) \\
d\sin\theta_m &= m\lambda \\
y_m &= L\tan\theta_m \\
I_{max} &= N^2 I_1 \\
\theta_p &= \frac{p\lambda}{a} \\
y_p &= \frac{p\lambda L}{a} \\
w &= \frac{2\lambda L}{a} \\
\theta_i &= \theta_r
\end{aligned}
$$

$$
\begin{aligned}
n_1 \sin\theta_1 &= n_2 \sin\theta_2 \\
s' &= \frac{n_2}{n_1} s \\
I_{scattered} &\propto \frac{1}{\lambda^4} \\
m &= -\frac{s'}{s} \\
\frac{n_1}{s} + \frac{n_2}{s'} &= \frac{(n_2 - n_1)}{R}
\end{aligned} \tag{2}
$$